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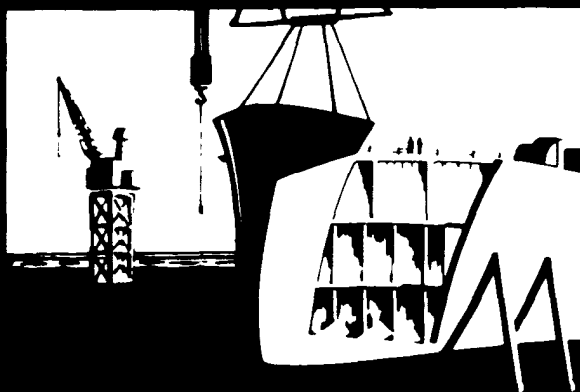
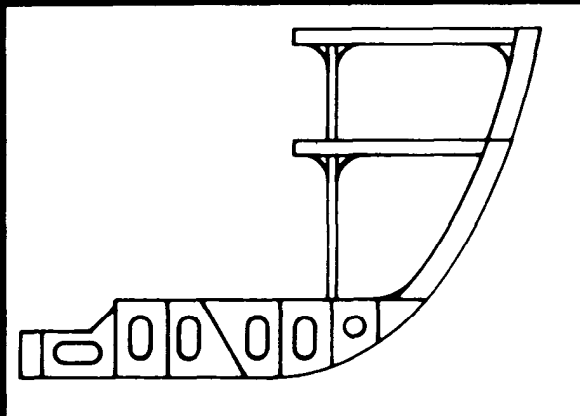
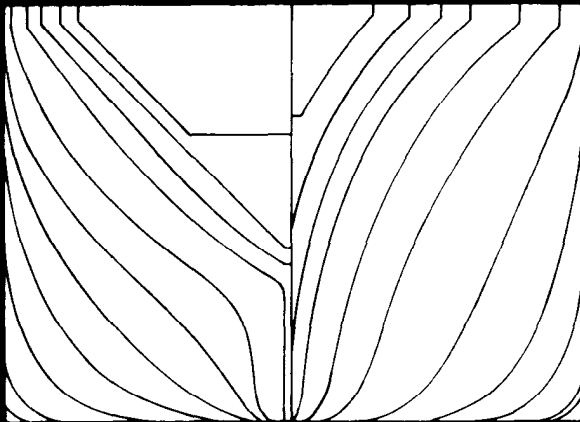
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HULL CONSTRUCTION TOLERANCE STANDARDS

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ABSTRACT

A project to develop a trial set of representative hull construction tolerance standards has been undertaken at Sun Ship. The trial standards will serve as a strawman to test for possible industrywide consensus in this sensitive area. The standards are being selected to include representative forming, distortion, alignment, fitup, plate fairness, and weld profile tolerances. Source material for these standards includes foreign commercial shipbuilding industry standards, U.S. Navy and Maritime Administration standards, and standards from individual U.S. and foreign shipyards. The project is jointly funded by the U.S. Maritime Administration and Sun Ship under the National Shipbuilding Standards Program administered by Bath Iron Works. The trial standards will be reviewed by the SNAME SP-6 Panel and will be submitted to ASTM F 25.04 for consideration and possible adoption as an Industry standard, if a consensus proves possible.

HULL CONSTRUCTION TOLERANCE STANDARDS

Background

We might begin by asking what exactly are hull construction tolerance standards and what significance do they have. Hull construction tolerance standards are those standards which define the required dimensional accuracy of the various component pieces and operations encountered in hull construction. These include cutting and burning accuracy, weld bead size and shape, forming accuracy, distortion and fairness, end alignment and fit-up.

Hull construction accuracy affects hull structural performance in areas such as fatigue and stability. It also has an effect on hull resistance, particularly if plate surface roughness and coatings surface roughness are considered. Coatings performance, and alignment and operation of mechanical systems are other items which may be influenced by hull construction irregularities. Rough passageways and uneven deck plates are unfriendly or even hazardous for crew and cargo.

Construction tolerances also affect appearance. While this may not be the most crucial consideration, it can't be ignored.

Accuracy requirements have a significant impact on hull construction costs. Tighter tolerances often add to construction costs. Overly stringent tolerance standards are therefore to be avoided.

On the other hand, improved construction accuracy during fabrication has a significant favorable effect on the subsequent cost of erection. In some cases, the added cost of improving the dimensional accuracy of sub-assemblies may be more than recovered by reduced erection costs on the building ways.

Hull Construction Tolerance Standards Worldwide

In many of the more advanced shipbuilding nations, including Japan, Sweden and Germany, national industry-wide hull construction tolerance standards have been developed to some degree or another. The most extensive of these standards is the Japanese Shipbuilding Quality Standard (JSQS) published by the Society of Naval Architects of Japan. These standards were first issued in the mid-sixty's after deliberation among shipbuilders, classification societies, and others. The construction tolerances given in JSQS reflect extensive accuracy measurements taken over the years in Japanese shipyards.

The Japanese standards employ a two level system for tolerances. The first level, called the standard range, indicates the general level of accuracy considered satisfactory to ship owners and classification societies. It might be thought of as the target level of accuracy for the shipbuilding process. The second level of accuracy called the tolerance limit, indicates the level of accuracy within which individual corrective action is not generally required. This might be thought of as the limit of acceptability for individual pieces or assemblies.

In typical application, the standard range impacts process control. Isolated excursions beyond the standard range would not require action, while frequent excursions beyond the standard range might indicate a need for tighter process controls. On the other hand, the tolerance limit impacts the individual piece or assembly measured.

In statistical terms, the Japanese have found that only 5% of their measurements fell outside the standard range, and only .3% fall outside the tolerance limit. If we assume a normal distribution for the measurements, these figures indicate that the standard range corresponds to a

range of two standard deviations, and the tolerance limit corresponds to a range of three standard deviations.

Hull Construction Tolerance Standards in the U.S.

Presently no industry wide hull construction tolerance standards exist in this country despite the widely felt desirability of having such standards. One possibility for remedying this lack is for the shipbuilders to unilaterally prepare and issue tolerance standards, with the concurrence of regulatory agencies, through an organization such as SNAME. There are several drawbacks with this approach, not the least of which is the possibility of legal action relating to antitrust or restraint of trade legislation. Moreover, a unilateral action by shipbuilders, even if acceptable to classification societies, might not gain wide acceptance among ship owners. It was felt that another approach involving participation of all segments of OUR industry would be preferable.

The Present Project

The present hull construction tolerance standard project undertaken by Sun Ship is part of the MarAd sponsored National Shipbuilding Standards Program managed by Bath Iron Works and steered by the SNAME SP-6 Panel. As is typical of the projects in this program, the objective is to develop industry standards which can be approved and issued through ASTM - in particular through its Shipbuilding Committee F-25.

The ASTM is the largest voluntary consensus standards organization in the world. Their due process approval procedures involve producers, users and general interest groups. Because of the broad representation, and the due process approval procedures, ASTM has acquired an immunity to anti-trust action. For the same reasons ASTM standards generally enjoy a high level of acceptance.

Direction of the Project

The present effort is a small pilot project, designed to begin the standards development process in the area of hull construction tolerances. The project began with a review of existing standards, including foreign national standards (Japanese, Swedish, German), U.S. Navy and MarAd standards, and Ship Structure Committee report SSC 273. This last document is a survey which gives some insight into U.S. practice, but has no formal standing in the industry. Also included in our review were several shipyard standards where available (U.S. and foreign).

From the existing standards, some 40 items were selected for the present project. These are individual standards which were thought to be reasonable and representative. The candidate standards were drawn from various of the sources listed above, and covered a variety of construction operations. The standards selected are intended to serve as a "strawman" - in other words trial standards to test for possible consensus. It is possible that achieving consensus will be difficult in this sensitive area. Shipbuilders and owners are likely to begin the process with somewhat different viewpoints, and consensus may be difficult in areas where subjective judgments and divergent interests are involved. The present effort should serve to point up problem areas in this regard and the results should serve as a nucleus for an ongoing standards development effort in this area.

The candidate standards were not chosen expressly on the basis of fitness-for-purpose, but it is expected that there is a relationship between the candidate standards and acceptable performance. The JSQS standards for example reflect actual Japanese shipbuilding experience and therefore these standards are generally relatable to the performance of Japanese ships constructed in that period. Other standards reflect analytical or experimental

work, or reflect the judgment and experience of knowledgeable practitioners.

Form of Proposed Standards

The organization of the present effort is outlined in Figure 1. The contents were selected to cover a representative cross section of the types of construction tolerances encountered in practice. Some specific examples of proposed construction tolerance standards are shown in Figures 2 through 7. Where appropriate, the standards include a two level system for tolerances, namely standard range and tolerance limit, as in the JSQS.

Figure 2 shows proposed tolerance standards for flange breadth and straightness, for flanged plate longitudinals. These standards reflect U.S. practice, per SSC 273, and are *also* comparable to JSQS standards.

Figure 3 shows proposed alignment standards for lateral alignment of flanges in longitudinals, and for alignment of intercostal joints. The first reflects Swedish shipbuilding standards, and the latter is a first cut for discussion in an area where there is presently a divergence among existing standards.

Figure 4 shows the proposed standard for fairness of critical hull plating. This standard is taken directly from the MarAd fairness specification and does not differ greatly from the corresponding Navy specification. The indicated tolerances are interpreted as tolerance limits.

Figure 5 shows proposed standards for local dents and weld depressions, again interpreted as tolerance limits. These standards are derived from the German shipbuilding standards.

Figure 6 shows proposed distortion tolerances for besms, frames, girders, and stiffeners. The standard range and tolerance limits shown are derived from the JSQS, and are consistent with the German Standards.

Figure 7 shows a proposed tolerance standard for stanchion straightness. The indicated standard range and tolerance limit are taken from the JSQS.

Remarks

In the present effort we define the standard range to be the level of construction accuracy which is normally expected to be achieved using conventional shipbuilding practice. The tolerance limit in the present effort is defined as the construction tolerance range within which no remedial action need be taken for the item in question. Construction inaccuracies falling outside the standard range, but within the tolerance limit, generally require no remedial action with respect to the element in question. However, if such inaccuracies are encountered frequently, it may indicate that processes controls should be reviewed and possibly tightened. Construction inaccuracies falling outside the tolerance limits may cause problems in service or at subsequent stages of construction and generally require remedial action.

The present candidate standards have been submitted to the SNAME SP-6 Panel for review and comment prior to their submission later this year to the ASTM Shipbuilding Committee F-25.

Where appropriate, standard corrective actions will also be indicated. It may not always be possible to identify a preferred all purpose corrective action. In many cases, the best course of action will depend on individual circumstances.

The proposed standards are intended to serve as a practical guideline for hull construction tolerances - a further clarification of U.S. practice. They would also be available to draw from if owner and builder agreed to make more binding arrangements regarding construction tolerances.

ORGANIZATION OF SELECTED STANDARDS

WELDING

- **SHAPE OF BEAD**

FABRICATION AND FORMING

- **FLANGED PLATE LONGITUDINALS**
- **FLANGED BRACKETS**
- **BUILT-UP SECTIONS**
- **PLATES**

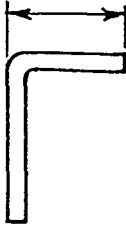
ALIGNMENT AND FITTING

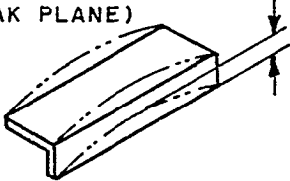
- **FITTING ACCURACY**
- **OPENINGS**

DISTORTION AND FAIRNESS

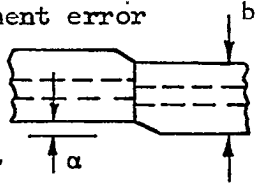
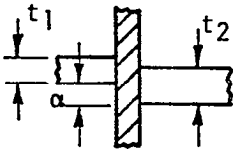
- **FAIRNESS**
- **LOCAL DENTS AND WELD DEPRESSIONS**
- **DISTORTION OF HULL FORM**
- **MISCELLANEOUS**

B. FABRICATION & FORMING

B-I FLANGED PLATE LONGITUDINAL	STANDARD RANGE	TOLERANCE LIMITS
<u>B-I.1</u> BREADTH OF FLANGE 	$\pm 1/8$ "	$\pm 1/4$ "

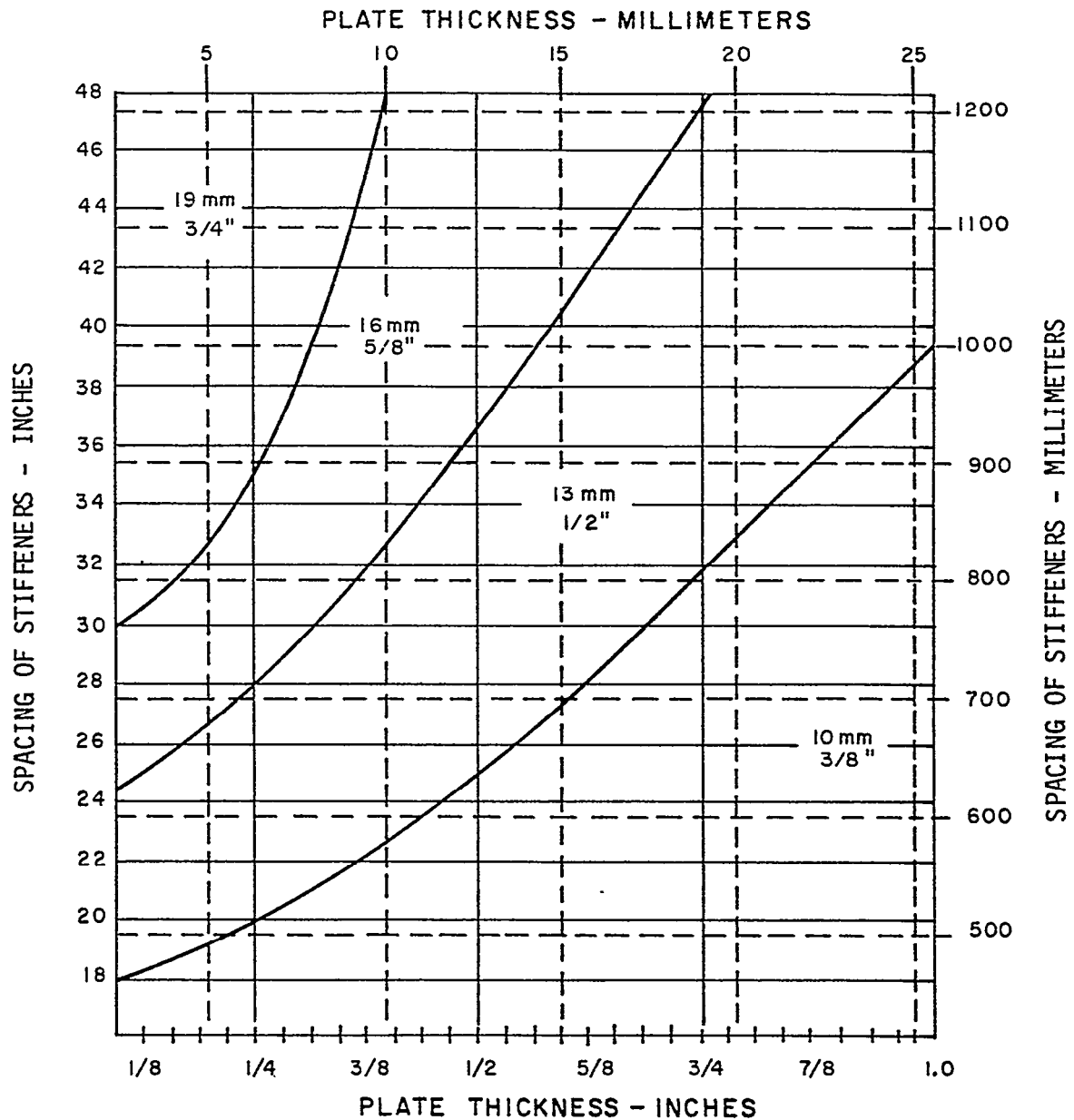
<u>B-I.4</u> CURVATURE OR STRAIGHTNESS IN THE PLANE OF THE FLANGE (WEAK PLANE)  Per 400 inches in length	$\pm 3/8$ "	± 1 "
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C. ALIGNMENT & FITTING

C- I FITTING ACCURACY	STANDARD RANGE	TOLERANCE LIMITS
<p><u>C-1.1</u> FLANGE IN TEE LONGITUDINALS</p> <p>Alignment error</p>  <p>Alignment of webs must meet standard for alignment of butt joints.</p>		$\alpha \leq .04b$ <p>(Max. 5/16")</p>
<p><u>C-1.2</u> ALIGNMENT OF FILLET JOINT</p> <p><u>Strength Member</u></p>  <p><u>Other</u></p> <p>α = DIFFERENCE t = THICKNESS $t_1 \leq t_2$</p>		$\alpha \leq \frac{t_1}{2}$ <p>But not to exceed weld size</p> $\alpha < \frac{t_1}{2}$

D- I. 1.2 FIGURE - 2

THIS FIGURE DOES NOT APPLY FOR LOCAL DENTS OR
WELD DEPRESSIONS. REFER TO SECTION D-2 FOR THOSE CONDITIONS.



This figure is applicable for the following areas:

1. Entire shell.
2. Upper most strength deck.
3. Longitudinal strength structure within the Midship 3/5 length which includes inner bottom tank top.

D. DISTORTION & FAIRNESS

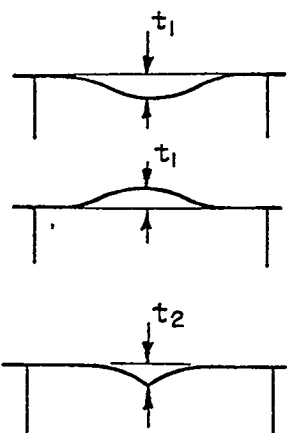
D-2 LOCAL DENTS AND WELD DEPRESSIONS	DEPTH t_1	DEPTH t_2
 <p data-bbox="690 892 901 945">LOCAL DENTS IN PLATE PANEL</p> <p data-bbox="682 1134 925 1186">UNFAIRNESS OF WELD DEPRESSION</p>		
<u>D-2.1</u> SHELL ABOVE WATERLINE BELOW WATERLINE	5/16 "	3/8 "
<u>D-2.2.</u> MAIN DK FREE AREA COVERED AREA	1/4 3/8	3/8

FIGURE 6

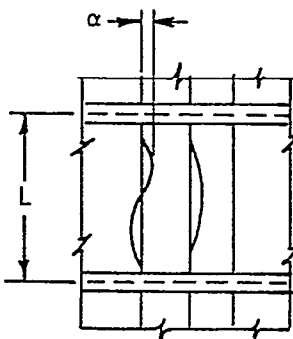
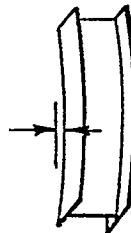
D-4.1. PERMISSIBLE DISTORTION OF BEAMS, FRAMES, GIRDERS AND STIFFENERS.		
Deviation from straight line between 2 points of support.		
	$L < 30''$	$\alpha \leq 3/16''$
	$30'' \leq L \leq 125''$	$\alpha \leq \frac{L}{500} + 1/8''$
	$L > 125''$	$\alpha \leq 3/8''$
		$\alpha \leq 5/16''$
		$\alpha \leq \frac{L}{500} + 1/4''$
		$\alpha \leq 1/2''$

FIGURE 7

D-4.5. DISTORTION OF 'H' PILLAR BETWEEN DECKS. CURVATURE IN EITHER PLANE.		
		
	$3/16''$	$1/4''$
TYPICAL LENGTH 10 FT.		

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